SATELLITE/TERRESTRIAL NETWORKS FOR OIL EXPLORATION

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ABSTRACT

In October of 1993, Amoco Corporation initiated the ARIES project. ARIES (ATM Research & Industrial Enterprise Study) was designed as a joint effort between the research and manufacturing units of the corporation to study the role of Asynchronous Transfer Mode in the next generation network.

Rather than theorize about the characteristics and performance of a network based on ATM, the ARIES team's goal was to build a real ATM network and study various communication models with the test network. Amoco enlisted the assistance of seventeen industry partners to build the five-node North American network. That work has been extended in 1995 to include many other participants from the energy industry with the oversight of the American Petroleum Institute.

The ARIES project has brought new partnerships to the communications industry, along with many early realizations about the benefits and drawbacks of ATM-based networks. Among the dramatic benefits demonstrated by the ARIES team is the exceptional agility that ATM networks give large organizations. This agility factor makes it possible for large corporations to respond very quickly to competitive pressure, business opportunity or crisis.

An important component of the global information infrastructure is satellite systems, which will extend the reach of existing networks to literally any point on the earth, or its atmosphere. Recognizing this, NASA has developed the Advanced Communications Technology Satellite as an on-orbit testbed for the development of satellite-based advanced communications models.

One area of work for the ARIES project is to demonstrate dramatic new capabilities based on the combination of terrestrial ATM networks and broadband satellite links. NASA's Advanced Communications Technology Satellite is one demonstration platform for this work. One specific application discussed in this paper involves the delivery of seismic data from ships at sea to computational facilities in the United States using ACTS technology. The successful development of this model could revolutionize the way the oil industry explores for fossil fuels.

INTRODUCTION

The petroleum industry has been engaged in exploration activities ever since the first major discoveries in Pennsylvania and Texas. Throughout the last century, however, the exploration frontiers have moved from Texas, New Mexico and Louisiana to very remote reaches of the earth.

The industry is engaged in exploration activities reaching from the deep waters of the Gulf of Mexico to the Gulf of Suez to Russia and the China Sea. The process of deciding where to drill for fossil fuel is technically complex, involving supercomputers and various technologies developed specifically for oil exploration.

The U.S. oil industry alone will spend more than $40 billion in 1995 supporting exploration activity internationally. The remote nature of the sites where exploration is being performed, combined with the dearth of telecommunications services and capabilities in those areas, require large data sets to be moved using magnetic tape and physical transport. As a result, the huge data sets must go through several format conversions from the time they are generated to the time decisions are actually made as to their validity and promise of producing a strike. The resulting time lag between data collection and drilling decision can be months.

Using ATM-based networks and shipboard broadband digital satellite terminals, the time required to make drilling decisions could potentially be compressed from months to days or hours. The purpose of the ARIES demonstration projects is to build working models to demonstrate the validity of this assertion. Two potential benefits are apparent;

> Reduce the cost of actually performing oil exploration by making the ship part of the iterative process.
>
> Increase the probability that drilling at a site will produce results. This is a by-product of the cycle time reduction and improvements in the quality of the data returned as a result of increased interaction with the acquisition vessel. The course of the vessel could also be altered based on data returned.

The current use of computers and telecommunications systems

The oil industry utilizes very complex processes to map the sub-surface of the Earth. These processes involve sending powerful pulses of sound through the Earth and measuring the responses with very accurate instrumentation. This process is known to the industry as seismic acquisition.

Seismic acquisition can be performed on-shore or off-shore. On-shore seismic researchers utilize powerful devices which shake the earth. Seismic sensors, known as geophones, then measure the responses and record them on magnetic tape. For off-shore seismic acquisition, very powerful bursts of sound energy are transmitted from ships into the ocean using air guns. The reflections are then measured with arrays of hydrophones which are towed behind the ships. The raw data are recorded on magnetic tape.

Whether the seismic process is operated on land or off-shore, the resultant raw data sets are huge (many billions of bytes of each). The data sets must then be transferred to central sites where supercomputers reduce them and make it possible to display the results. In today's environment, moving and managing these large data sets is a major undertaking, as the data sets are generated very remotely. The ARIES model for the future of seismic acquisition makes the process interactive by combining high-performance digital satellites with the existing terrestrial network. Figure 1 depicts a seismic acquisition vessel and its associated equipment.

Due to the remote nature of exploration, the cost of these activities is necessarily very high. Moving people and equipment to remote locations introduces challenges in infrastructure, maintaining quality of life and transportation, just to start. The cost of these operations is often measured in $ billions. As a result, major multinational corporations will often form partnerships in the form of project teams to share the risk, cost and hopefully, the eventual reward of the exploration activities.

As an example, Amoco Corporation, Shell Oil Company and Exxon recently embarked on a joint exploration activity in the deep water of the Gulf of Mexico. The drilling rig, called the "Ram Powell" cost $1 billion to construct. Similarly, a group of major oil companies have teamed up to explore for oil and natural gas in the former Soviet Union. The project, which involves building airports, cities, schools, and of course exploration infrastructure, is estimated to cost at least $10 billion just to get started.

Satellite-Enabled Models

The ARIES team has developed a series of models which creatively apply telecommunications technology to the seismic acquisition and computational process. The models, if effective, have the potential to revolutionize the process of collecting, disseminating, visualizing and collaborating over seismic data. The models, which are described in the following paragraphs, can reduce the latency between the data collection and making a drilling decision from months to weeks, or even days.

It is important to note that the models are all satellite-enabled and require a large amount of bandwidth. Further, due to the fact that the data sets must travel a long distance from a moving platform, traversing many different types of physical media and covering a broad range of transmission speeds, the applications are also ATM-enabled. Therefore without a networking technology like ATM, the models would be very difficult, if not impossible, to build. Also, without the Advanced Communications Technology Satellite, the models would be impossible to demonstrate.

The ARIES team has developed a strong relationship with the National Aeronautics & Space Administration's Lewis Research Center team to facilitate the development and demonstration of these important models using ACTS.

The model

The model involves a ship at sea, towing an array of hydrophones behind it. The ship is moving at approximately five nautical miles per hour. Mounted on the ship at its stern is an air gun which shoots powerful bursts of sound energy into the ocean every 20 seconds. The array of hydrophones, which can number in the hundreds, measures the reflections returned from the sound pulses and records the results to magnetic tape. Simultaneously, the results are sent to an on-board ATM switch, which is connected to a satellite terminal. The data set is transmitted through the satellite to a supercomputer site in the U.S. where some preliminary processing is performed.

Using a terrestrial ATM network, the early results are delivered to a group of researchers representing the companies involved in the joint survey. The researchers are distributed across the U.S., but the high-performance network makes it possible for them to jointly manipulate and visualize the data. From this vantage point, the researchers are able to "steer the ship" to get a better look at areas of potential interest.

This model differs radically from the current methodology. Today, by the time the data sets are able to be visualized, the ship has long since left the area. Therefore, the researchers must do their best to make decisions based entirely on data returned from the original survey.

Series of demonstrations

ARIES is engaged in a series of demonstrations which will build upon each other to deliver a complete operational model described above.

The first demonstration - Washington, DC - December 8, 1994

This demonstration utilized an ACTS T1 VSAT mounted on an offshore production platform in the Gulf of Mexico. A small seismic data set was delivered through the satellite to a downlink site in Clarksburg, MD. The data set was incorporated into a terrestrial ATM network and delivered to Houston, TX where it was processed. The terrestrial network consisted of a combination of three carrier ATM services operating at 45 megabits per second.

Two researchers - one in Houston, TX and the other in Washington, DC were able to visualize the results of the computation simultaneously using a collaborative application running over the same terrestrial ATM network that delivered the raw data set. This demonstration was designed to take the first step toward the fully collaborative shipboard model using a small, proprietary data set from a fixed platform offshore.

The second demonstration - Cleveland, Ohio - September 13, 1995

The second demonstration, which is being run in conjunction with the ACTS Results Conference in Cleveland, Ohio on September 13, 1995 is designed to take the next step toward the full working model. The data set used will be the 3-Dimensional Synthetic Seismic Data Set (See Appendix). This data set is very similar to the actual data sets returned from the offshore acquisition process and is owned by the industry.

This demonstration also differentiates itself from the first by engaging the high data-rate (HDR) capabilities of the ACTS spacecraft. The data transfer will be conducted across ACTS links operating at 155 Mbps (OC-3c) - 100 times faster than the first demonstration. Finally, the second demonstration distributes the data downlink, computation and collaboration across multiple sites in the U.S., among multiple companies connected using a multi-carrier terrestrial ATM network. Figure 2 depicts the network used for the second demonstration.

The third demonstration -

The third ARIES demonstration is slated for early in 1996 and will utilize the ACTS broadband mobile terminal technology developed at the Jet Propulsion Laboratory. The broadband mobile terminal will be adapted for mounting on an actual seismic vessel operating offshore. The data acquisition equipment on-board the ship will be adapted to transmit parts of acquired data through the satellite, in addition to recording it on magnetic tape on-board.

The terrestrial portion of the network for the third demonstration will closely resemble the terrestrial network used for the second demonstration. The third demonstration will represent a fully functional system which will allow the oil industry and its government partners to study methods of applying satellite technology to the exploration process. It is important to note that the models developed for shipboard could also be used for seismic survey activities in very remote locations on land. Figure 3 depicts the conceptual network topology of the third demonstration.

The role of ACTS

The ARIES team has been were working on many new communications models as a part of the ARIES project. The project originally started with a very network-centric orientation, being based solely upon Asynchronous Transfer Mode, or ATM technology. Since many of the new models that ATM would enable were high-performance in nature, the ARIES activities naturally were skewed toward research applications and oil exploration.

One of the biggest problems the industry faces involves moving and managing very large data sets that are generated in remote places, such as Siberia or in the middle of the ocean. Since it isn't possible to call up North Sea Telecom and order a fiber optic extension cord to seismic acquisition vessels, the project sought ways to transfer the data using high-performance satellite links.

It is important to note that before ATM, the broadband satellite-based model would probably not have been feasible, since the different transmission media involved would have made it difficult to implement. Since ATM networks operate independent of physical media, speed and geography, the model could be constructed. The Advanced Communications Technology Satellite made it possible to actually demonstrate the model.

ACTS was very well suited to objectives of the project. The ARIES broadband satellite model required a transmission path from remote sites that resembled a fiber optic line in speed and performance (low bit error rate). There was also some likelihood that that the path would need to be bi-directional, which ACTS was equipped to support. Since the satellite was already aloft, the concept could be demonstrated on a real satellite. The only thing missing was an articulated antenna for shipboard use. This is the subject of the third demonstration project slated for February, 1996.

CONCLUSIONS

Oil exploration is one one of the "Grand Challenge" class of computational problems. The ARIES team hopes to deliver the high-performance network which will work in concert with distributed high-performance computational engines which will eventually break the computational barrier to making the process truly interactive.

The ultimate goal of this activity is the development of commercially deployable technologies and services which will be used to revolutionize the petrochemical industry. The development of these technologies and services will have additional applicability in other sectors, including education, health care, entertainment and defense.

Using the Advanced Communications Technology Satellite, the ARIES project is demonstrating the viability of K/Ka band satellites for unique business applications. The project also demonstrates effective public/private partnerships to solve problems which would be much to costly or complex to solve as individual organizations. Finally, ARIES and NASA are reducing the collective risk of deploying advanced technologies by sharing best practices promoting technology transfer between the public and private sectors.

APPENDIX

The 3-D Synthetic Seismic Data Set

Four national laboratories of the U.S. Department of Energy have partnered with the Society of Exploration Geophysicists (SEG) and the European Association of Exploration Geophysicists (EAEG) to establish the 3-Dimensional Synthetic Seismic Data Set (3-D SSD). The SSD represents the first ground truth data set available to assist geophysicists with the development and testing of seismic processing and visualization applications.

When it's completed, the SSD, which is housed at the National Storage Laboratory at Lawrence Livermore National Laboratories in Livermore, CA, will be nearly one terabyte in size. Industry researchers will be able to use the SSD to validate seismic algorithms by navigating "virtual vessels" through the data set.

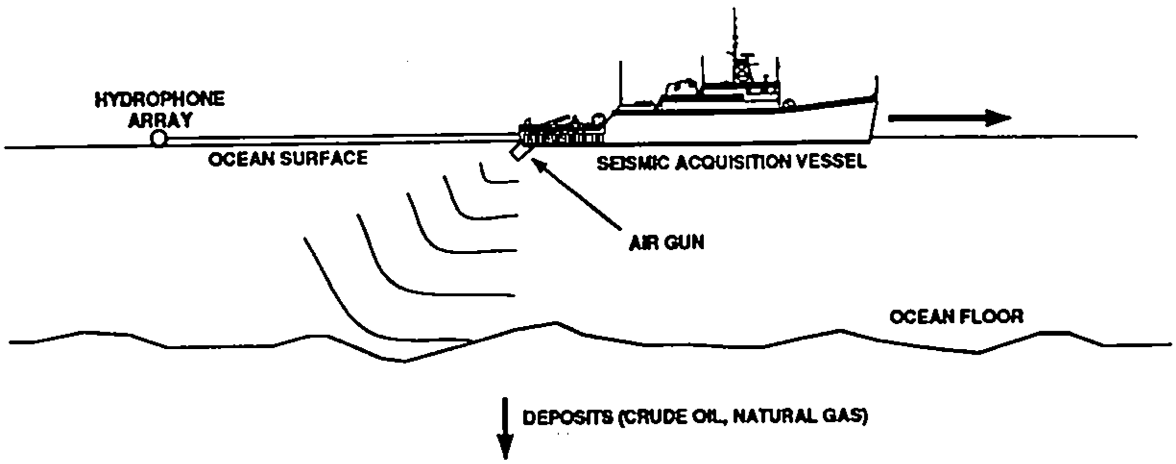

Figure 1: *The current exploration model*

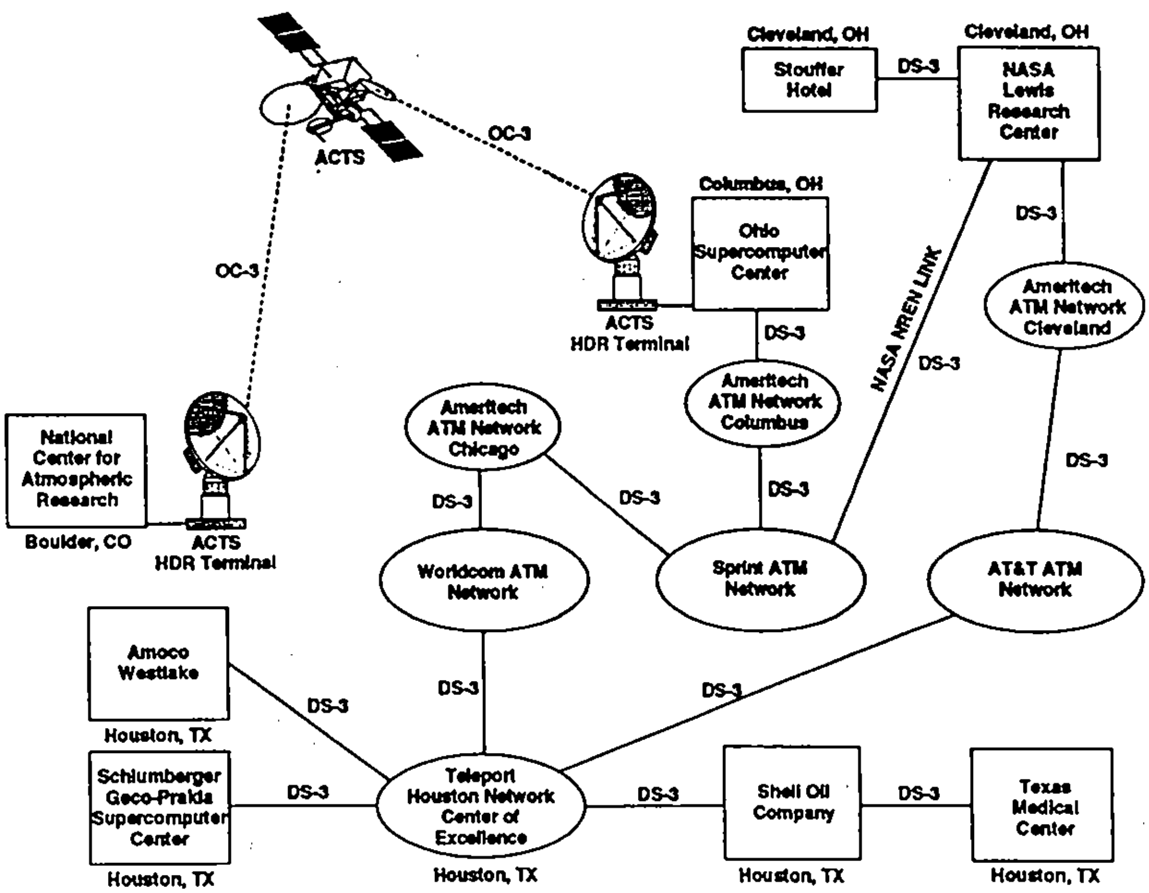

Figure 2: *Network diagram of the second ARIES demonstration*

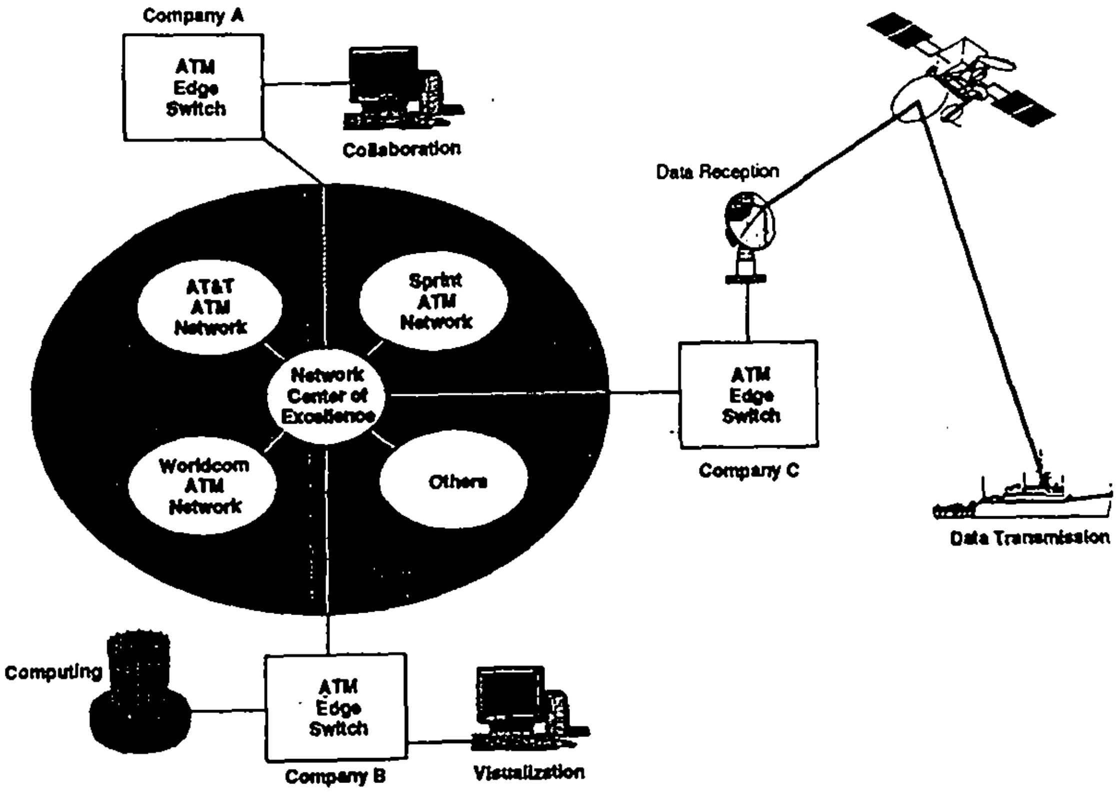

Figure 3: *Network diagram of the third ARIES demonstration*